UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE (GENERAL) DEGREE LEVEL II (SEMESTER I) EXAMINATION – SEPTEMBER/OCTOBER 2018

SUBJECT: PHYSICS

COURSE UNIT: PHY2114

TIME: 2 hours & 30 minutes

PART II

Answer FIVE (05) Questions only

All symbols have their usual meaning.

a) State the first law of thermodynamics in mathematical form. Identifying each term.

[04 marks]

b) An ideal gas changes its state from (P_1, V_1, T_1) to (P_2, V_2, T_2).

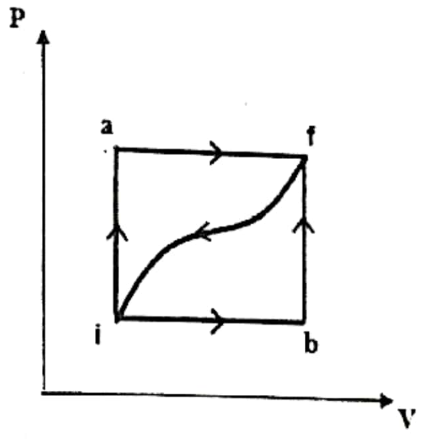
(i) If the above process is adiabatic, obtain an expression for the work done by the gas during the process in terms of P_1, P_2, V_1, V_2 and γ, where, $\gamma = C_p/C_v$. C_p and C_v are the heat capacities at constant pressure and constant volume, respectively.

[04 marks]

(ii) If the above process is isothermal, obtain an expression for the work done by the gas during the process in terms of V_1, V_2, T_1 and other standard constants.

[03 marks]

c) The diagram shows two possible paths, iaf and ibf, that a system can change from state i to state f and a possible path of change fi, from f to i.



It is found that the heat absorbed by the system, $\Delta Q = 500$ J and the work done on the system, $\Delta W = -200$ J along the path iaf, while along the path ibf $\Delta Q = 360$ J. The internal energy of state i is $U_i = 100$ J.

(i) Calculate U_f. [03 marks]

(ii) Calculate ΔW along the path ibf. [02 marks]

(iii) If $\Delta W = 130$ J along the curved path fi, find ΔQ for this path.

[03 marks]

(iv) If $U_b = 220$ J, find ΔQ for the two processes of ib and bf separately.

[06 marks]

2. a) State the Kelvin-Planck statement of the second law of thermodynamics. [03 marks]

b) (i) Show that the molar specific heat capacity of a monatomic ideal gas at constant volume can be written as $c_v = 3R/2$. [04 marks]

(ii) Show that $c_p - c_v = R$ for any ideal gas. Where c_p is the molar specific heat capacity of the ideal gas at constant pressure. [03 marks]

c) A sample of 1 mole of a monatomic ideal gas is taken through a cycle (ABCD) shown in the figure below. At point A, the pressure, volume, and temperature are P_i, V_i and T_i, respectively.

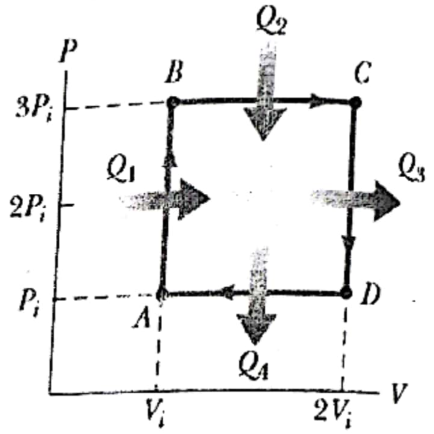
In terms of R and T_i, find

(i) the total heat energy entering the system per cycle. [07 marks]

(ii) the total heat energy leaving the system per cycle. [04 marks]

(iii) the efficiency of an engine operating in this cycle, and [02 marks]

(iv) Explain how the efficiency compares with that of an engine operating in a Carnot cycle between the same temperature extremes. [02 marks]



3. a) Write down the Maxwell's equations in thermodynamics. [04 marks]

b) Using those equations derive the first and second TdS equations. [10 marks]

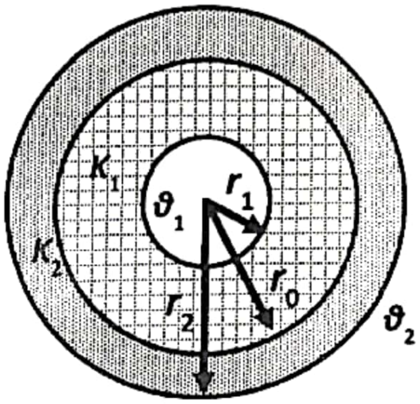
c) (i) Using the first law of thermodynamics and the first TdS equation, obtain the internal energy equation $\left[\frac{\partial U}{\partial V}\right]_T = T\left[\frac{\partial P}{\partial T}\right]_V - P$ [07 marks]

(ii) Using above results, show that $\left[\frac{\partial U}{\partial V}\right]_T = 0$ for a perfect gas. [04 marks]

4. a) (i) Inner and outer radii of a spherical shell are a and b respectively. The temperatures of the inner and outer surfaces of the shell are maintained at θ_1 and θ_2 ($\theta_1 > \theta_2$) respectively. The thermal conductivity of the material of the shell is K. Show that the rate of heat transfer in radial direction within the shell can be given as $\frac{4\pi K ab(\theta_1-\theta_2)}{(b-a)}$.

[07 marks]

(ii) A system consists of two concentric spherical shells made up of two materials with heat conductivities K_1 and K_2 as shown in the figure. The inside and outside temperatures of the system are θ_1 and θ_2 ($\theta_2 < \theta_1$) respectively. Obtain an expression for the rate of heat flow through the system.



[08 marks]

b) (i) State the Stefan's law of radiation. [04 marks]

(ii) If the solar radiation energy falling on a unit area of the earth per second is 1400 $Jm^{-2}s^{-1}$, calculate the temperature on the surface of the Sun.

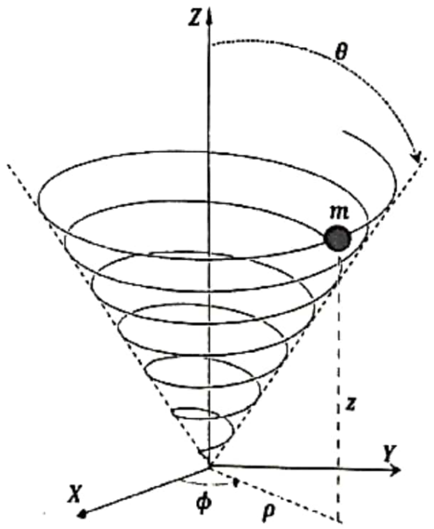
Distance from Sun to earth (R) = 1.5×10^{11} m

Radius of the Sun (r) = 6.9×10^{8} m

The emissivity of the Sun (e) = 1

Stefan's constant (σ) = 5.7×10^{-8} $Js^{-1}m^{-2}K^{-4}$ [06 marks]

5. A bead of mass m is constrained to move along a smooth conical spiral as shown in the figure. θ is a fixed constant angle. Considering the height of the bead at a given time as z from the XY plane, the coordinates on the spiral are given by $\rho = \alpha z$ and $\phi = \beta z$ for constants α and β.



a) What is/are the generalized coordinate(s) of the system? [03 marks]

b) Write down the Lagrangian for the system. [10 marks]

c) Are there any cyclic coordinates? Give reasoning. [04 marks]

d) Determine the equation(s) of motion for the system. [08 marks]

(**Hint**: Use cylindrical polar coordinates.)

6. Two identical one-dimensional harmonic oscillators (mass m and natural frequency ω_0) are coupled by a harmonic force of natural frequency α. For small displacements, the kinetic energy (T) and the potential energy (V) of the system in terms of the generalized coordinates x and y are given by

$T = \frac{1}{2}m(\dot{x}^2 + \dot{y}^2)$ and

$V = \frac{1}{2}m\omega_0^2(x^2 + y^2) + \frac{1}{2}m\alpha^2(x - y)^2.$

a) Find the normal coordinates of the system for small displacements.

[06 marks]

b) Find the normal frequencies of vibrations of the system for small displacements.

[10 marks]

c) Determine the normal modes of vibrations of the system for small displacements.

[06 marks]

d) In which normal mode the masses are moving out of phase? [03 marks]

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